II.—ESSAYS ON SPECULATIVE GEOLOGY.

1.—ON HOMOTAXIS AND CONTEMPORANEITY.

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IN any inquiry into the history of the earth as a whole, we are met at the outset by a serious difficulty. In human affairs a general view of history, not confined to a single country, would be practically impossible, were we ignorant of the relations of the various eras from which different races reckon their dates: thus, it would be impossible to write a connected account of the history of Europe in the classical period were it not possible to determine the relation of the Olympian era to that dating from the foundation of the city of Rome. Yet the supposed case is not unlike that to which the geologist addresses himself when he endeavours to make a connected survey of such widely-separated regions as Europe, India, Australia, and America.

In the supposed case of the Greek and Roman eras, there are numerous points of contact, principally dates of battles, which, having been recorded by both nations according to their own system, enable us to compare the two, and so to determine what would be the date of any event, recorded by the one, had it been recorded by the other. But in geology we have no such points of contact; there is a very general tendency to regard any two series of beds, in which a few fossil forms specifically identical are found, as of contemporaneous origin. That this view is erroneous, and that it would be nearer the truth to say that two widely-separated beds, in which the same forms are found, could not be of *contemporaneous* origin, was long ago pointed out by Forbes and Huxley, the word *homotaxis* being invented by the latter to express the relation existing. More recently, at the Montreal meeting of the British Association, Dr. Blanford went into the question at length, and fully showed how erroneous is the assumption, often tacitly made, that similarity of included organic remains indicates contemporaneity of origin of the beds in which they are preserved.

Be it understood that I am in no way desirous of depreciating the value of palæontological evidence; but, for the purpose of what may be called historical geology, the merely approximate contemporaneity indicated by homotaxis, however perfect, is by no means sufficient. What we desire is something approaching to the accuracy of dates in written history, rather than that vague "homotaxis" indicated by the Stone or Bronze ages, with which we have to be satisfied in what is known as the Pre-Historic period of human history. As long as we are dealing only with the history of a single limited region, no serious difficulty is likely to arise; but when we try to bring the history of, say, Australia and Europe, into relation with each other, a doubt may well arise as to whether beds which would be classed as Lower Carboniferous if they occurred in Europe can be really considered as of that age when measured by European standards.

This is a question that palæontology alone can never answer finally, and we are consequently compelled to search for some other evidence which will enable us to say, in some cases at any rate, that the beds are or are not strictly contemporaneous in their origin. One possible means would be the traces left by a period of cold similar to the well-known "Glacial period" of Post-Tertiary times. That there was such a period during which an arctic climate penetrated into temperate regions has been amply proved, and we may, I think, safely assume that this "Glacial" period of cold was contemporaneous in both hemispheres; for, whatever may have been the cause of the colder climate which prevailed during that period, it must have affected both hemispheres in the same manner at the same time.

I am not overlooking the fact that the most probable theory of the Glacial period, that of Dr. Croll, necessitates the glaciation of one hemisphere contemporaneously with the prevalence of a mild climate in the other; but if we take the Glacial period as a whole, which includes all the minor glacial and interglacial periods, we may say that the Post-Tertiary deposits which show signs of a colder climate than now prevails are of contemporaneous origin, wherever they may be found. By this I must not be understood to mean that any one particular bed in one place can be declared to be contemporaneous with a definite bed anywhere else, but that the series as a whole were of contemporaneous origin, though the actual limits may not have been the same in both cases.

If we can prove that similar Glacial epochs have occurred during the sedimentary period, using the term to denote that period of the Earth's history which is represented by the sequence of sedimentary formations, we shall have an important check on the palæontological timepiece, by which we can determine whether it is fast or slow. To prove this it will not be sufficient merely to point out that evidences of glacial action have been detected by various observers in strata of various ages, and in latitudes lower than those in which icebergs are met with at the present day; but if it can be shown that, in several widely-separated regions, and in strata which can on independent grounds be shown to be, at least, approximately homotaxial, there are to be found extensive indications of glacial action, which are not seen in the beds above or below, we may safely and fairly conclude that they all belong to a single Glacial epoch comparable to that of Post-Tertiary times.

For this purpose I shall take that Glacial period represented by the Talchir beds of India, the Ecca beds of Africa, and certain beds in Australia likewise of glacial origin. I choose this particular instance because the details are more familiar to me than any other, and moreover I shall be able to place before the readers of this Magazine some recent additions to our knowledge of the geology of these countries.

It must be well known that there have been serious differences of opinion regarding the age of the Indian and Australian Coal-measures, and that this difference has practically been between the field geologists on the one hand and the palæobotanists on the other. The former regarded them as of Carboniferous age, or, at the latest, representing the interval between the Palæozoic and Mesozoic eras of Europe, while the latter, judging only from the plant remains found with the coal, declared it to be of Mesozoic and even of Jurassic age.

As regards the palæontological relations of these beds to each other, and to the plant-bearing series of South Africa, the subject has been so thoroughly treated by Dr. Blanford in his address that it will be needless for me to enter into a repetition of the subject. I may, however, remark that both in India and South Africa there is a series of sedimentary formations which, if identity of fossils were proof of contemporaneity, would have to be regarded as of contemporary and even coeval origin, and in both cases there are at the lower limit of the series beds whose structure proves that they must have been deposited through the agency of floating-ice. In Australia there are some beds (the Bacchus Marsh beds of Victoria) which similarly show that there must have been ice floating in large masses on the sea beneath which they were deposited : these beds have yielded a limited flora composed of three species of *Gangamopteris*, of which one is identical with and the other two closely allied to Talchir species.

Thus we see that in India, in South Africa, and in Australia there are beds whose nature indicates the existence of ice floating at or near the sea-level, in latitudes which it does not now reach, and that, as judged by the fossil plants contained in them and in the associated beds, they must be regarded as homotaxial. The conclusion is well-nigh irresistible that they all belong to a single Glacial epoch, and are consequently strictly contemporaneous in origin.

So far, I do not think any one will object to my conclusions ; they have been foreshadowed by Mr. H. F. Blanford,[1] and as far as India and Australia are concerned by Dr. Feistmantel,[2] who is by no means disposed to underestimate the value of palæobotanical evidence, even where opposed to every other consideration ; and so far I have been able to accept and summarize Mr. Blanford's address. But in extending the same line of reasoning, and in trying to determine even approximately the true date of this Glacial period, I shall have to enter on more disputable ground, and to refer to information acquired since Dr. Blanford's address was delivered.

The first point to notice is that the Bacchus Marsh beds of Victoria are not the only instance of Glacial boulder-beds occurring in Australia ; for in New South Wales traces of Glacial action are abundant in the marine beds below the Coal-measures. I am not aware of any published record of this fact previous to my own notice of the fact[3]; but, as long ago as 1861, the lithological resemblance, as seen in a collection of specimens from New South Wales, between the marine beds of the Wollongong district and the boulder-beds of the Talchirs, was noticed by the late Dr. T. Oldham.[1] That any special stress should have been laid on the resemblance was not to be expected, for when the words were written the Glacial origin of the Talchir boulder-bed had not been universally acknowledged, the very idea of a Glacial epoch was still strange, and no one had yet dreamed of a Palæozoic Glacial epoch, still less of using such a conception in the correlation of distant deposits. These observations appear to have dropped completely out of sight, and when I found that in Mr. W. T. Blanford's reply to Dr. Feistmantel[2] no notice was taken of this resemblance, although Mr. H. F. Blanford's suggestion that the Glacial beds of the Permian in England and the Talchirs in India were contemporaneous is quoted, I concluded that private information of later date had led to a modification of the views expressed as to the lithological resemblance of the beds.

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[1] Quart. Journ. Geol. Soc. Lond. vol. xxxi. p. 519.

[2] Proc. Geol. Surv. Ind.

[3] Proc. Geol. Surv. India, vol. xix. p. 43 (1886). The substance of this paper and of another in the Journ. As. Soc. Beng. for 1884, is incorporated in the present essay.

Nevertheless, when visiting Australia in 1885, I determined to pay special attention to this point, and was not surprised, on examining the section west of Newcastle, to find that the marine beds showed abundant traces of Glacial action. Blocks of slate, quartzite and crystalline rocks, for the most part subangular, are found scattered through a matrix of fine sand or shale, which contain delicate *Fenestellæ* and bivalve shells with the valves still united, showing that they had lived, died and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks of stone now found lying side by side with them. These included fragments of rock are of all sizes, from a few inches to several feet in diameter, the largest I saw being about four feet across in every direction as exposed in the cutting, and of unknown size in the third dimension; and I was informed by Mr. Wilkinson that in these same beds he has seen boulders of slate, etc., whose dimensions may be measured in yards.

It is impossible to account for these features except by the action of ice floating in large masses,[3] and I had the good fortune to discover, during the course of a short morning's walk, in the railway cutting near Branxton, a fragment beautifully smoothed and striated in the manner characteristic of glacier action, besides at least two others which showed the same feature, though obscurely. This seems to show that the ice was of the nature of icebergs broken off from a glacier which descended to the sea-level.

Beds of similar structure and indicating a similar mode of origin are also found at Wollongong, south of Sydney, and in the Blue Mountains. Though these have not been traced into connection with the marine beds west of Newcastle, the similarity of their position, fauna, and physical aspect, all leave little room for doubt that they are of the same age. Beds of similar aspect have been described by Mr. R. L. Jack, in Queensland. These beds—also of marine origin, and indicating the presence of ice floating in the sea by which they were deposited,[1] contain 22 species of fossils, so far as the fauna is known, of which 15 are also found in the marine beds of New South Wales, and only seven have not been found to the south.

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[1] Mem. Geol. Surv. Ind. vol. iii. p. 209 (1863).

[2] Rec. G. S. I. vol. xi. p. 148 (1878).

[3] Roughly speaking, it may be said to take 26 cubic feet of fresh-water ice floating in sea-water to float a cubic foot of granite, or 14 cubic yards to float one ton. It must be remembered that many of these fragments probably came from a distance, and that the ice was melting all the while. These figures must be reduced by two-fifths if the rock is supposed to be immersed.

As the case stands, there are in Australia two sets of beds, both of which indicate the presence of floating-ice in the water in which they were deposited. One of these, the Bacchus Marsh group, is shown by its plant fossils to be homotaxial with the Talchir group of India; the other has yielded a marine fauna of Lower Carboniferous facies, as judged by European standards, and a limited flora which, however, does not show any direct relation to that of the Bacchus Marsh beds.

I am not aware of any published attempt to correlate the Bacchus Marsh beds with a definite horizon in New South Wales before Dr. Feistmantel in 1880 gave it as his opinion that they were the equivalents of the Hawkesbury Sandstones. This opinion, so far as I can glean from his published writings, was based on the so-called Lower Mesozoic facies of the Bacchus Marsh flora, and was supposed to be confirmed by Mr. C. S. Wilkinson's discovery of glacial action in the Hawkesbury Sandstones. Mr. Wilkinson thus describes this evidence[2]—"In the sections exposed in the quarries at Fort Macquarrie, Woolloomooloo, Flagstaff Hill and other places, may be seen angular boulders of shale[3] of all sizes up to 20 feet in diameter, imbedded in the sandstone in a most confused manner, some of them standing on end as regards their stratification, and others inclined at all angles. They contain the same fossil plants that are found in the beds of shale from which they have evidently been derived. These angular boulders occur nearly always immediately above the shale-beds, and are mixed with very rounded pebbles of quartz; they are sometimes slightly curved as though they had been bent while in a semiplastic condition, and the shale-beds occasionally terminate abruptly as though broken off."

It is difficult, if not impossible, to account for these appearances, except by the action of ice in some form or other; the angular form of the fragments of shale shows that in some manner they must have been indurated before disturbance, and it is impossible to account for this induration of what must then have been recently deposited mud except by the freezing of the interstitial water. This supposition would accord with the general nature of the evidence, which indicates the action of ground-ice, such as is formed during the severe winters of North America, rather than the presence of large masses of floating-ice; and hence does not necessarily indicate so severe a climate as that afforded by the Bacchus Marsh beds of

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[1] Report on the Bowen River Coal-field, by R. L. Jack, Esq., F.G.S., Brisbane, 1879.

[2] Notes on the occurrence of a remarkable boulder in the Hawkesbury Rocks, Trans. Roy. Soc. N. S. W. xiii. 105 (1884).

[3] Which is interbedded with the sandstones.

Victoria, which, according to the late Sir R. Daintree, contain "strata, mainly composed of fine mud, dotted thoughout with various-sized, generally rounded, pebbles, and those pebbles mostly unknown in the vicinity, and some not yet seen in place so far as the Geological Survey has extended a minute examination[1];" further on he says that "blocks of granite, in some instances over a ton in weight, are found imbedded in a matrix of soft mud[2];" and in the last progress report by the Secretary for Mines in Victoria, Mr. Murray states, on the authority of the late Sir R. Daintree, that some of these granite boulders resemble no granite that occurs as a rock-mass nearer than Queensland.[3]

This contrast in the nature of the evidence of glacial action shows that, if this form of argument is at all admissible, it is with the Lower Carboniferous marine, rather than with the Hawkesbury glacial beds that we must associate those of Bacchus Marsh.

Nor can palæontology be said to support Dr. Feistmantel's hypothesis; for *Gangamopteris*, the only genus of plants known from the Bacchus Marsh beds, is found neither in the plant-bearing beds, interstratified in the Lower Carboniferous marine group, nor in the Hawkesbury group. It has, however, been found in the intervening Newcastle group, and one species is identical with a Bacchus Marsh form; moreover, the only other species of *Gangamopteris* in the Newcastle beds is, according to Dr. Feistmantel, closely allied to one of the Bacchus Marsh species. This fossil evidence would by many be regarded as sufficient to prove the contemporaneity of the Bacchus Marsh and Newcastle groups; but the beds of the latter show no trace of glacial action, so that the former cannot be referred to that age in face of the existence of evidence of glacial action in the beds above and below. A reference to Dr. Blanford's address will show that whereas a very close relationship exists between the floras of the Newcastle and Lower Coal-measures, there is next to none between those of the former and the Hawkesbury Sandstones; and I may add that the stratigraphy of the beds appears to point to the same conclusion as the palæontology; so that, as the choice lies between the two, it is again rather with the Lower Carboniferous marine than with the Hawkesbury group that we must associate the Bacchus Marsh beds.

The Bacchus Marsh beds are not known to occur in conformable contact with any other group; but there is a large tract of country covered by an upper group of the same series, which is characterized by the occurrence of *Tæniopteris Daintreei*, a form which occurs in New South Wales in the beds overlying the Hawkesbury and Wianamatta groups. Owing to the large area covered by more recent lava flows, the exact relation of the two groups is unknown; but there can be little doubt that they are unconformable, for the Bacchus Marsh beds are overlapped by the *Tæniopteris* beds, which rest unconformably on the older Palæozoics. This would imply a greater difference of age than seems to obtain between the Hawkesbury and overlying groups in New South Wales. To this I may add the difference in induration of the two, which is such that when originally surveyed, the Bacchus Marsh beds were believed to be Devonian, and are coloured on the original survey sheets as Upper Palæozoic.

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[1] Geological Survey, Report on the Geology of the District of Ballan, by Richard Daintree, p. 10, Melbourne, 1866.

[2] *Ibid.*, p. 10.

[3] Geological Survey, Progress Report by the Secretary for Mines, p. 80, Melbourne, 1881.

As a further confirmation of the opinion ventured on, I may point to the relationship that exists between the flora of the Damudas which overlie the Talchir group in India, and that of the Newcastle beds, which occupy a similar position above the Lower Carboniferous marine group in Australia.

To begin with, both floras are marked by the predominance of the genus *Glossopteris*, which, in the Newcastle flora, comprises nine out of 26 species, or 35 per cent. of the total number of species, and 19 species out of 63, or 30 per cent. of the total number of species in the Damuda flora; of these, one species, *G. browniana*, is identical in both cases, and three Newcastle species, *G. linearis*, *G. ampla*, and *G. parallela*, are represented by the allied Damuda species, *G. angustifolia*, *G. communis*, and *G. damudica*. The genus *Phyllotheca* is represented in both floras, and the Australian form is allied to, and was long considered identical with, the *P. indica* of the Damudas. *Vertebraria* is found in both series, and is only known elsewhere from the "Jurassic" beds of Siberia. *Sphenopteris alata*, Brong., is another species represented by allied forms in the Damuda flora, and *Gangamopteris angustifolia*, M'Coy, is common to the two floras. Besides these the genus *Noeggerathiopsis* is represented in both floras, so that we have in all six genera and two species common to the two floras, besides five species represented by allied forms. In other words two-thirds of the genera and more than a quarter of the species of the Newcastle flora are represented in that of the Damudas.

Taking all these points into consideration, I think we may safely affirm that the Talchirs of India, the Ecca beds of South Africa, the Bacchus Marsh beds in Victoria, and the Marine beds below the Newcastle Coal-measures in New South Wales, were all deposited contemporaneously, and that during their deposition there prevailed a Glacial epoch comparable to, if not even more severe than, that of the Pleistocene period.

This conclusion brings out the contradictory nature of the Palæontological evidence even more strongly than it was possible for Dr. Blanford to do in his address, for it shows that the coexistence of a Jurassic flora with a Carboniferous fauna was no mere local phenomenon, but that the Jurassic flora had established itself over nearly half a hemisphere, while the Carboniferous Mollusca were still inhabiting the seas.

In the face of this contradiction, it may be allowable to doubt whether either form of palæontological evidence can be regarded as absolutely trustworthy, and to question whether the beds containing the Lower Carboniferous marine fauna may not have been deposited synchronously with the deposition of the Permian Boulder-beds of England, and with certain Boulder-beds which are known to exist in North America at about the same horizon. It is, however, at present impracticable for me to follow up this question for want of access to books of reference; but this is of comparatively minor importance, as my purpose has merely been to show that there have been glacial epochs comparable to that of the Post-Tertiary period; and having shown that such a glacial epoch did at one time affect a large portion of the Earth's surface, it becomes easy to acknowledge that similar periods of cold have occurred before and since, and that we must not attempt to ascribe every occurrence of Glacial beds of Tertiary or Pre-Tertiary age to some merely local cause. And having acknowledged this, we at once obtain what was wanted, a check on the palæontological timepiece, a time-signal on the chronograph of the world.

Note.—A month ago I would have appealed, as proof positive of the contentions stated above, to the discovery in the Salt Range of the Punjab of marine fossils identical with those of the Australian Carboniferous beds. These are derived from beds which exhibit ample proofs of glacial action, and were on that ground assumed by Dr. Waagen to be of the same age as the Talchirs, which he agreed with most of the members of the Geological Survey in regarding as of Palæozoic age. The pebbles in which the fossils were found might in hand-specimens be taken for concretionary nodules, and an imperfect description of their mode of occurrence would support this idea; moreover the coincidence of the fauna and physical conditions with those of the Australian beds is very striking. There was every temptation for me to accept Dr. Waagen's conclusions, but a careful examination of the beds, and of the mode of occurrence of the fossils, has convinced me that this is a mere coincidence, and that the fossils, which occur as transported pebbles, can consequently be of no use in determining the homotaxis of the beds from which they are derived. The stratigraphical relations of these beds are such as to associate them with the Nummulitics; and as boulder beds, presumably of glacial origin, have been recorded by Mr. Lydekker as conformably underlying the Nummulitics of Ladák, there is no difficulty in finding a horizon to which the beds can be referred.

III.—Essays on Speculative Geology.

2.—Probable Changes of Latitude.

By R. D. Oldham, A.R.S.M. etc.

Part I.—Glacial Periods in Low Latitudes.

In my last essay I had occasion to refer to the former existence of icebergs in localities which now lie in latitudes lower than those in which glacial action is known to have reached, even during the last Glacial period. But, surprising as it may be to find evidence of glacial action within a few degrees of, and, as in the case of the Bowen River Coal-field, a few degrees within, the tropics, this sinks into insignificance in the face of the evidences of repeated Glacial periods that may be found in India, and especially in the Himalayas.